Inventory of economic models

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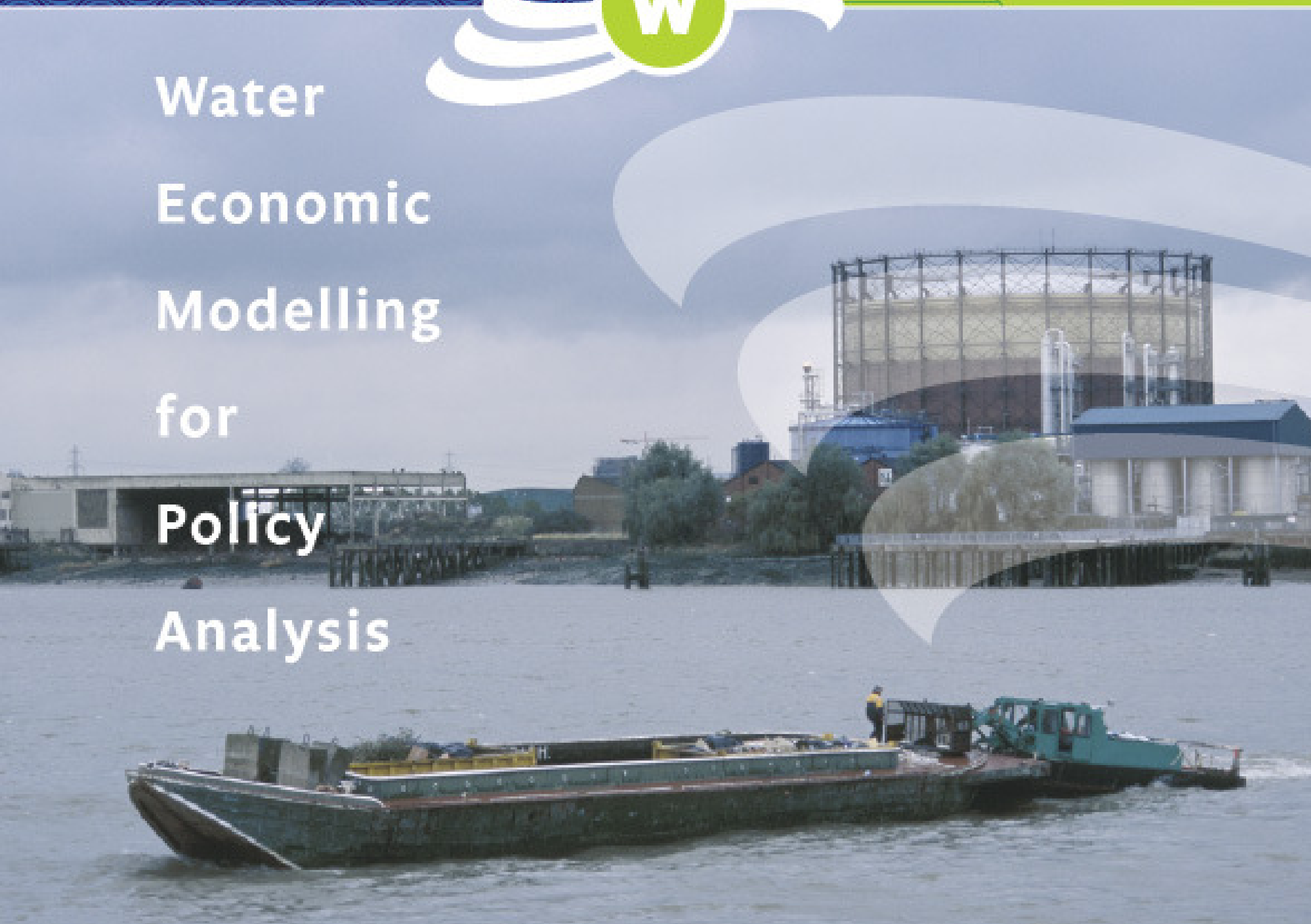
WEMPA

Water
Economic
Modelling
for
Policy
Analysis



Inventory of economic models

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Summary

The aim of the BSIK project 'Water Economic Modelling for Policy Analysis' (WEMPA) is to develop an integrated and operational water and economy model framework of the Netherlands. This model will enable the analysis of the economic effects of measures to improve the water quality and subsequently the ecological quality of rivers, regional and local waters. The model must be shaped in such a way that it is suitable for economic analysis of implementing the EU Water Framework Directive (WFD) in the Netherlands.

This underlying document addresses the availability and usefulness of international hydro-economic models, national economic models and sector economic models to become a part of the WEMPA-model framework. Both applicability at the national as well as the regional scale will be considered.

In the short-term, the project focuses primarily on the WFD and the effect of the implementation on the Dutch economy. The long-term objective is to use WEMPA to simulate the multiple relationships between economy and the water system for policy analysis.

The intention is to construct the model framework first and thereafter to analyse which models are most suitable to implement in this framework. This means that an inventory is needed of available models and that screening and selection is needed of all potential suitable models to determine which of them provide essential information to be used in (a portion of) the framework.

For reasons of transparency and clarity, the screening of economic and water system models is done in a comparable way using a screening and evaluation system. This system is hierarchical and consists of five levels of evaluation and screening criteria.

All screened models are described in this document in separate sections and the models that passed the screening procedure are discussed in more detail. The foreign hydro-economic models are likely to provide information about the modelling framework that could be used to develop the WEMPA. None of the hydro-economic models taken into account passes to the second level, due to the fact that they are not able to model water quality issues at national level and to produce relevant results at the national level. Therefore, the national economic models were assessed seriously, to determine whether they are suitable to be integrated in WEMPA. The national economic general equilibrium models (see Gerlagh et al., 2002, for the calculations of Sustainable National Income and the DEAN model in Dellink, 2003) are most useful to implement in the WEMPA framework, although they do not fully fit the screening criteria. Sector models have been analysed to determine whether these models are suitable to integrate in the model framework. DRAM and Atlantis are suitable models for agriculture and drinking water respectively. The Water Recreation model does not pass all screening levels, but is the only relevant model for this sector.

At a lower aggregation level bio-economic models provide more detailed insight into the effect of possible measures. However, the economic component of these models is rather weak, and they do not go beyond the farm level.

1. Introduction

The aim of the WEMPA project is to develop an integrated and operational water and economy model that will enable us to determine the economic effects of measures to improve the water quality and subsequently the ecological quality of rivers, regional and local waters. An important requisite of this model is that it must be shaped in such a way that it is suitable for applying cost effectiveness analysis of implementing measures within the EU Water Framework Directive (WFD) in the Netherlands. The existing models used to assess cost-effectiveness of measures are usually not integrated and are either pure hydrologic models or economic models. With this integrated model, we will be able to analyse the economic effects of implementing measures in a particular economic sector, and the impacts on other economic sectors as well. Eventually, the integrated water and economy model should be able to select the most efficient combination of measures to fulfil the goals of WFD.

The interchange of information between model components of the economic and hydrological realms is described in the inventory of water system models (Baan and te Linde, 2005). In this report the focus is on economic models that have been coupled to hydrological models or can be coupled in the remainder of this project. For an efficient allocation of WFD measures over sectors the value attached to the use of water by these sectors is important. The use of water should be broadly interpreted; also the emission of substances to water bodies is regarded as water use. The allocation of measures within the Dutch economy requires that the model has to describe the relation between the sectors distinguished within the Netherlands. This relation is commonly described by modelling the relevant markets. Also the water use of each sector has to be incorporated, this is usually done incorporating water use in the sector's supply and demand.

This report addresses the availability and usefulness of (water) economic models to become a part of the model framework to be developed. In this report, the focal point is the economy, while Baan and te Linde (2005) focus attention on water system models. In Chapter 2, the literature is reviewed to obtain the state of the art of combining hydrology and economics into one model (or the combination of hydrologic and economic models). Chapter 3 describes the evaluation and screening procedure of the potentially relevant system models. Based on the results of the screening procedure models will be selected to become part of the model framework. Chapter 4 is dedicated to hydro-economic models. A short characterization of each model is given. The screening procedure is applied in Chapter 5. At the end an overview is presented of the selected models. Conclusions are drawn and recommendations for the development of the integrated model framework are formulated in Chapter 6.

2. Literature review and conceptual framework

2.1 Literature review

Although recent river basin modelling studies have recognised the necessity of integrated approaches, either the economic or the hydrologic component usually dominates in river basin models, which often depends on the background of the researchers and on the set of issues examined. Whereas hydrologic-based studies include comprehensive and detailed hydrologic and system control components, the economic component is rather simple such as cost-benefit analyses or aggregate water delivery objectives. On the other hand, the emphasis in economic studies has been mainly on economic relationships (like input/output analyses) without comprehensive hydrological modelling.

According to McKinney et al. (1999), the relationships in hydro-economic modelling should allow for the effective transfer of information from one component to the other. Before this goal of integration can be achieved, a number of barriers has to be overcome. First, hydrological models often use simulation techniques based on a set of rules governing water allocation and infrastructure operation, whereas economic models predominantly use optimisation routines to determine the most efficient allocation of resources based on an objective function and accompanying constraints (Ringler and Cai, 2003). Linear programming seems to be best suited for determining reservoir capacity. General equilibrium models are based on entire watersheds whereas partial models address the optimisation at farm level. Modelling of the demand for and the value of water requires a decision rule to determine the farmer's optimal choice of optimal cropping pattern, water use, conditioned on input costs and prices of agricultural products (see Heinz and Eberle, 2002).

Second, the boundaries in the economic system might not be the same as those of the hydrological model. In addition, the economic and hydrologic components often use different time intervals and time horizons. Economic models use generally larger time intervals. In hydrologic models the time interval has to be small enough to reflect the real-world processes.

McKinney et al. (1999) present an overview of models that integrate hydrologic and economic components; those models either use the compartment modelling approach or the holistic modelling approach. Under the compartment approach, there is a loose connection between the different economic and hydrologic components, and only output of one compartment is usually transferred to other compartments and used as input. Under the holistic approach, there is one single unit with both components tightly connected to a consistent model, and an integrated analytical framework is provided. For the holistic modelling approach, the key issue is to define the essential relationships between the economic and hydrologic components, so that the economic analysis can be realised based on a meaningful physical system, see McKinney et al. (1999).

Cheesman (2004) presents rather obvious decision criteria for selecting the appropriate water use model. E.g. 'if the study's objective is to assess the impact of alternative water allocation strategies on welfare outcomes, economic models are appropriate'. 'Heterogeneous aquifers should be modelled with a distributed parameter approach.'; and

'Value estimators from environmental service flows associated with different groundwater states should be obtained. These value estimates should be incorporated as parameters, not constraints, in the optimization objective function.'

The modelling framework used by Ringler and Cai (2003) includes three components: (1) hydrologic components, such as the water balance in reservoirs, river reaches, and crop fields, (2) economic components, such as the calculation of benefits from water use by sector, demand side, and (3) institutional rules and economic incentives that have impact upon the hydrologic and economic components (see Figure 2.1).

Giraud et al. (2002) describe an integrated model that is composed of three interconnected hydrological modules representing the river, the aquifer and the soil simulating water transfers from one to the others. Three behavioural modules portray key water users: the irrigation canal manager, two types of farmers and the canoe renter. These economic actors have their own strategies supported by behavioural rules that enable them to modify both water quantity and quality of surface and ground waters.

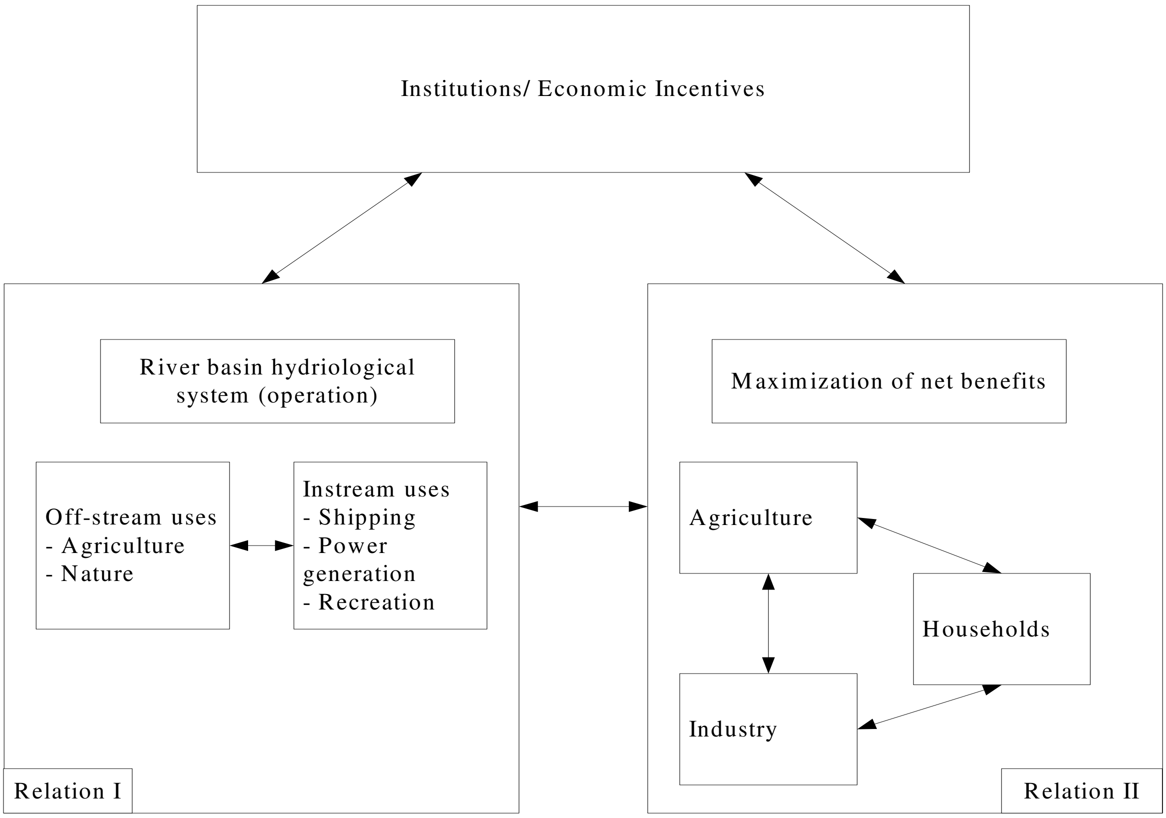

Figure 2.1 Schematic representation of hydro-economic model (see Ringler and Cai, 2003).

2.2 Conceptual framework

The project Water Economics Model and Policy Analysis (WEMPA) for the Netherlands is based on the schematisation in Figure 2.1. The relations that have to be modelled by the economic model components become clear:

I. The relation between the water subsystem; in casu water quality (emission of environmentally detrimental outputs) and the economic subsystem; in casu output (or other variable that accounts for production). This relation is often captured in water use models.

II. The relation between the distinguished economic sectors through markets for inputs (inputs of one sector interact with inputs of other sectors [economic linkages at the input side] or through markets for outputs (outputs of one sector are related to outputs of other sectors) [economic linkages at the output side].

Since we intend to use existing models or parts of it, we introduce a typology of models that link hydrology and economy, see also Baan and te Linde (2005). With this typology we are able to assess models from the hydrological and economic literature. The typology distinguishes 6 types of models:

1. General economic models predicting the economic activity related to other sectors and dependent on the economic development.
2. Sector models predicting the economic activity related to the quantity of water available and the emissions generated.
3. Emission models predicting the emission of pollutants to the environment (to air, water and soil).
4. Input load models predicting the input load of pollutants into water bodies.
5. Water quality models predicting the quality of water depending on the input loads of pollutants. If absorption to sediment is important, interaction with sediment models is arranged.
6. Effect models predicting the effect of changes in water quality on sectors.

Baan and te Linde (2005) discuss models of categories 3, 4 and 5 as in these kind of models, hydrology is the dominant aspect. Models of category 1 are purely economic models and will be described in this report. Models of category 2 and 6 are a mixture of economic and water system aspects. If economic aspects dominate, these models will be described in this report, otherwise they are discussed in Baan and te Linde (2005). [1]:

Integrated models focus especially on the relation between the hydrologic part and the economic part (relation I), while general equilibrium models emphasise the relation between different sectors (relation II). In the characterisation of the models analysed the strengths and weaknesses of these relations are discussed.

Although the WFD focuses on water quality, possible measures to attain the (chemical) goals of WFD are likely to affect water quantity as well (see Van der Veeren, 2005). In the case for agriculture, WFD measures are expected to affect water quality as well as the water levels of water bodies.

In addition to the scheme of a hydro-economic model in Figure 2.1, we identify four basic environment-economy linkages that have to be part our water economic model:

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[1] Emission models predicting the emission of pollutants to the environment and effect models predicting the effect of changes in water quality (or water quantity) on sectors are not elaborated in this report.

A. Emissions into the environment are related to the production (economic activity);

B. Economic production changes due to the possible abatement measures;

C. The model should include interactions between economic sectors or agents (in terms of factor inputs, intermediate deliveries, consumption) and should be able to aggregate results over sectors (at least the division into three sectors agriculture, industry and households).

D. The model should be able to take into account possible feedback effects of improved water quality on the economic activity (production and consumption.

With those four environment economy relationships, we reviewed the existing economic literature, and we distinguished three categories of models. Firstly, hydro-economic models include all four relations. Secondly, national economic models usually take into account the interactions between economic sectors (relation C),and they might be extended with the impacts of abatement measures (relation B) or with emissions related to economic activity (relation A). Finally, sector models mainly focus attention on the impact of abatements measures on economic production (of the sector). These sector models might be extended with emissions related to economic activity (relation A) and feedback effects of improved environmental quality on production (relation D). Typically, interactions with other economic sectors are ignored.

Hence with various combinations of existing models we might be able to connect the relevant relations. In the next chapter, we develop a screening procedure to select the model that will be integrated in the hydro-economic model.

2.3 Conclusions

An integrated hydro-economic model is not available for the Netherlands or its river basins. To answer the research questions of the WEMPA project adequately such an integrated model has to be built. In this report, we focus attention on the essential economic elements of such a model.

3. Evaluation and screening procedure

3.1 Introduction

The aim of the WEMPA project is to develop an integrated and operational water and economy model framework for the Netherlands. With this model we will be able to determine the economic effects of measures within the WFD to improve the quality of rivers and regional and local waters. We intend to build a framework of existing models or parts of it rather than develop a whole new model, so that we review the literature on water system and economic models to make an inventory of available models. With the resulting list of models, we develop a selection procedure in order to screen models on their usefulness for our modelling framework.

For reasons of transparency and clarity, the screening of economic and water system models use a similar selection procedure (see Baan and te Linde, 2005). In this selection, models move on through five subsequent levels of criteria. With the level of screening, the level of detail increases and the number of models being scrutinized decreases. The models are first screened in a qualitative way. Important aspects are for instance if a model is based on recent data or if information on the model is lacking. Models that satisfy the criteria of a certain level of screening are passed on to the subsequent level of screening. If a model passes all five screening levels, it is considered suitable as part of the model framework.

Each model is screened both for usefulness at a national level and at a regional level. This is done as models are needed operating on both a national scale (for the short term), and in a later stage of the project, on a regional scale.

The screening procedure is based on a list of models and it is flexible, so that it can be repeated in a later stage of the project if goals may be redefined. In other words, the set-up is as generic as possible to allow the framework to be used throughout the WEMPA project. The database can be used for other purposes as well.

At each screening level, a distinction is made between:

- general criteria giving information on and a characterisation of the model;
- specific criteria giving information on water system models;
- specific criteria giving information on economic models;
- criteria dealing with the usefulness of the models for policy analysis;
- selection criteria.

3.2 At zero level

In Chapter 2, we distinguished three categories of models from the literature, hydro-economics models, national economic models, and sector models. Each category contains a number of models (see appendix A). A full screening procedure of all those models is unnecessary, because some models are outdated, for some models it is clear beforehand that other models are more useful, and for others it may be very difficult and time consuming to collect the necessary screening information. Therefore a qualitative screening is applied on an extensive list of models. Qualitative screening criteria include: outdated/updated, considered useful/ not useful etcetera. The models passing this qualitative screening will pass on to the first screening level.

3.3 At first level

At the first level of screening we assess the broad characteristics of the models. Specific evaluation criteria for the economic models are:

- what kind of model is it?
- where does it fit into the modelling chain?

In particular, at this stage broad goals of the project are considered:

a. is the model able to address *national* water policy and management issues?

b. is the model able to address *regional* water policy and management issues?

c. does the model fit into the modelling chain"?

d. can the model be used to contribute to the assessment or evaluation of financial or economic effects of water policy measures?

If the answer to one of these questions is no, the model does not pass on to the next screening level. However, there is one exception: if the answer to criterion (b) is no, while the answers to all other criteria are yes, the model passes the screening test as it may be useful for analyses and assessments at the national level.

3.4 At second level

The second screening level considers more specific model aspects. Specific evaluation criteria for the economic models at this level are:

- what water use functions / emission sources are being distinguished?
- which substances are included in the calculations?
- is there a check against emission and /or water quality standards?
- are demand and supply functions specified?

Screening takes place on the general suitability in terms of the specific goals of the project. The screening criteria are:

a. is the model useful for analysis of the issues that are defined as 'priority' also considering ease of use and expected accurateness of results?

b. are relevant water use functions and /or emission sources included?

c. does the model deal with priority substances of the WFD?

d. is the desired input data available?

If the answer to one of these questions is no, then (for the moment) the model does not pass this screening level.

3.5 At third level

The third level of screening assesses models for specific suitability for the specific goals, as well as appropriateness in terms of spatial and temporal dimensions for use within the modular framework. Specific evaluation criteria for the economic models at this level are:

- what are possible linkages with other parts of the model chain and with other economic models?
- what is the temporal scale of calculations?
- what is the spatial scale of calculations?
- what is the temporal scale of results?
- what is the spatial scale of results?
- does the model includes seasonality?
- is it possible to down-scale or up-scale results?

The screening criteria are:

a. can the model contribute to the evaluation of specific measures to achieve water quality standards on a *national* scale?
b. can the model contribute to the evaluation of specific measures to achieve water quality standards on a *regional* scale?
c. does the model produce accurate and reliable result that can be used for the assessment of water policy measures? If not, is there an alternative assessment tool that should be preferably used (e.g. another model, expert judgment)?

If the subsequent answers of both questions under (c) is no, the answer to this question becomes yes (negative times negative is positive).

If the answer to one of these questions is no, the model does not pass to the next screening level. There is one exception: if the answer to criterion (b) is no, and the answers to all other criteria are yes, the model passes the screening test as it may be needed for the short term for analyses and assessments at the national level.

3.6 At fourth level

The fourth level takes into account any other criteria necessary for assessment of WFD measures. Specific evaluation criteria for the economic models at this most detailed level are:

- are the input data for the model available?
- can the model be used to run different kind of scenarios with different kind of WFD measures or measure programmes?
- can the model be used to do (systematic) sensitivity analysis?

4. Description of relevant models

This Chapter reviews the relevant water and economy models from the economic literature. First, we collect information water system or economic models for the Netherlands. Then, hydro-economic models for foreign river basins are added to the list of models to be reviewed, as these models exemplify the type of water-economic model our project is aiming at. For the descriptions of (water economic) models we use three categories identified in Chapter 2 (see also Baan and te Linde, 2005):

i. Hydro-economic models, integrating hydrologic and economic knowledge.

ii. National economic models predicting the economic activity related to other sectors and dependent on the economic development.

iii. Sector models predicting the economic activity related to the quantity of water available and the emissions generated.

We distinguish between sector economic models, and national economic model. The first category describes the water use within a sector (relation I, see Figure 2.1) and the intra-sectoral markets. Three sectors are distinguished in WFD (agriculture, industry and households) and they are subject of further elaboration in WP6. National economic models are supposed to integrate the relevant sectors (relation II and III, see Figure 2.1) and offer (in some cases) relations between economics relations and emissions (or abatement costs). First, Dutch sector models are treated. Finally foreign models are given that might provide suitable modules for incorporation in the water-economic model.

4.1 Hydro-economic models

Hydro-economic models provide a tool for a systematic assessment of two complementary measures of the resource opportunity cost and the opportunity cost of the management measures required to achieve the objectives (e.g. minimum streamflow) in a water resources system. Theses values, which change dynamically in space and time, can serve as indicators for policy analysis. The models that are taken into account are (with section number):

- Maipo-river model (section 4.1.1)
- Danube-river model -RIWU-model (section 4.1.2)
- Herault-model (section 4.1.3)
- CHESS (section 4.1.4)
- PEGASE (section 4.1.5)
- Aquatool (section 4.1.6)
- Water wise (Waterwijs in Dutch, section 4.1.7)

4.1.1 Maipo-river model

Introduction

With growing scarcity and increasing competition for water across sectors, the need for efficient, equitable, and sustainable water allocation policies has increased in importance in water resources management. Therefore an integrated hydro-economic model has been developed for the Maipo river basin in Chile (Rosegrant *et al*., 2000).

Interaction water economics

The integrated hydro-economic model accounts for the interactions between water allocation, farmer input choice, agricultural productivity, non-agricultural water demand, and resource degradation in order to estimate the social and economic gains from improvement in allocation and efficiency of water use. The river basin model is based on a node-link network. Nodes represent physical entities and links stand for the connection between these entities. There are two sets of nodes included in the model: 1) source nodes, such as rivers, reservoirs, and groundwater aquifers, and 2) demand nodes, such as irrigation fields, industrial plants, and households. Both water quantity and water quality in terms of salinity are simulated in the model.

Scale and temporal aspects

The model has been applied to the Maipo river basin in Chile. Because the model has a generic form and structure it can be applied to others basins as well. The model has also been used for the Mekong delta (Ringler and Cai, 2003). The temporal scale is a 1-year time horizon with a monthly time step.

Scenarios and policy measures

The focus of the model is on the agricultural sector and to a lesser extent on the non-agricultural water sectors. Although the results of the model show the effectiveness of the model for policy analysis and water allocation in the river basin, additional research is needed. In further research more comprehensive policy analysis will be carried out.

4.1.2 Danube-river model -RIWU-model

Introduction

The regional-economic RIWU-model (Regional Industrial Water Use) describes the development of economics, demography and industrial water use in the Upper Danube (Bavaria, Germany) catchment area at the smallest possible spatial dissolution (Langmantel and Wackerbauer, 2003).

Interaction water economics

RIWU is based on the assumption of a representative profit-maximising industrial firm, which uses two local inputs, land and water. RIWU consists of eight model equations with which seven endogenous variables are forecasted. The exogenous variables are foreign sales and the area of land, the latter provisionally assumed to be constant. The calculated industrial water demand and industrial water extraction are depending both on the costs of water extraction and on industrial value added which is positively correlated with regional water exports and negatively correlated with the price of land.

Scale and temporal aspects

RIWU is – as it already says – a regional economic model. Therefore, analyses are made on regional scale. Although it is developed for the Upper Danube basin (an area of 77 000 km^2), RIWU can be transferred to other river basins. Furthermore, RIWU is able to calculate economic-environmental interactions at the level of the 96 districts of Bavaria. A RIWU simulation has been performed for the period 1995-2005.

Scenarios and policy measures

RIWU proved to be an appropriate tool to forecast regional economic development and industrial water use. It turned out that water scarcity and raising water prices have only a small impact on a region's industrial growth. RIWU can be used for water resource management.

4.1.3 Herault-model

Introduction

The river basin model Herault accounts for the interaction between water-allocation, farmer input choice, agricultural productivity, non-agricultural water demand, and resource degradation in order to estimate the social and economic gains from improvement in the allocation and efficiency of water use (Giraud *et al*., 2002).

Interaction water economics

The river basin modelling system is developed as a node-link network, in which nodes represent physical entities and links represent the connection between these entities. The nodes included are (1) source nodes, such as rivers, reservoirs and groundwater aquifers; and (2) demand nodes, such as irrigation fields, industrial plants, and households. At each agricultural demand site, water is allocated to a series of crops, according to their water requirement and economic profitability. Both crop area and yield are determined endogenously in the model. An existing hydrologic model has been adapted to the case study context; and a prototype optimisation model has been developed in order to estimate economic returns to water use. Both in-stream and off-stream water uses are considered in the model. The valuation of both water uses is implemented in a unified economic objective function, which is constrained by hydrologic, environmental and institutional relations.

Scale and temporal aspects

The model includes all the essential relationships of the components in a 1-year time horizon with a monthly time step.

4.1.4 CHESS

Introduction

Continuous models are inherently input data intensive and extremely difficult to calibrate and validate. Over the last two decades many studies have attempted to evaluate the impacts of climate change on watershed water quantity and quality. One achievement of the climate change research in the UK was to link dynamic biogeochemical models of different domains, e.g. rivers, estuaries and coastal waters, and to use the linked model to investigate possible changes from the current status that might occur in the future especially as the result of climate change. The Climate, Hydrochemistry and Economics of Surface-water Systems (CHESS) project has taken the linked methodology forward by exploring possible impacts of climate change on the water quality of European rivers, with the purpose of informing future catchment management (Boorman, 2003). The CHESS project has explored effects of climate change on the water quality of European rivers, with the purpose of informing future catchment management.

Interaction water economics

The integrated modelling framework required by CHESS had three elements that are closely linked:

- a catchment model representing soil and vegetation processes that can simulate the generation of water and chemical fluxes from catchment areas,
- an in-stream model that combines the flows from catchments with discharges from industries and sewage treatment works, and represents the transportation of water and biogeochemical processes within the channel network, and,
- techniques for linking the models and identifying appropriate scales at which to implement the models.

Around the modelling framework elements are required for the investigation of climate change impacts:

- Study catchments representing different European catchment types,
- Scenarios representing future climatic conditions, and,
- Methods of assessing and describing water quality

In Figure 4.1 we observe the schematic representation of the CHESS project. Note that the emphasis is on pollution from agriculture through eutrophying pollutants.

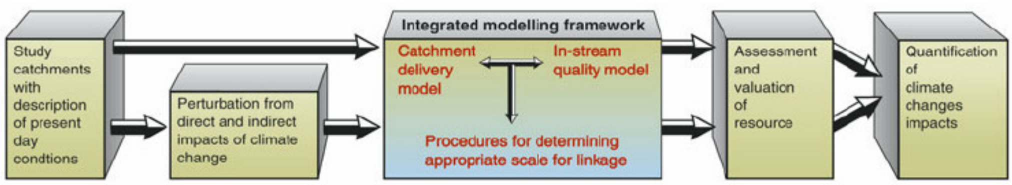

Figure 4.1 Schematic diagram of the major components in the CHESS project (CHESS, 2001).

Within the CHESS project different models were used for similar purposes and results were compared to determine strengths and weaknesses of different approaches.The authors conclude that "CHESS would also have benefited from other improvements in modelling methodologies. The first of these would be to have a range of available methods that match the data availability. Perhaps some of the modelling in CHESS has relied too heavily on models that are too sophisticated and demanding in terms of their data needs. Simple methods might provide better means of comparing catchments and identifying those with particular problems that require more data to be collected, or, indeed, justify the use of more sophisticated models. It is also apparent that to ensure consistency of model applications there must be greater standardisation in the application of models so that different users working independently are likely to produce similar results." (CHESS, 2001, p.25). This was achieved by the application of a standard modelling framework to a set of five European catchments located in Finland, United Kingdom, Belgium, Italy and Greece. Baseline conditions were simulated using existing meteorological data, and the modelling framework was able to reproduce key indicators of the flow and water quality regimes of the study catchments. The modelling framework comprised two models. The Soil Water Assessment Tool (SWAT) was used to simulate water and chemical fluxes, primarily nutrients and sediment, generated from diffuse areas and thereby provide sub-catchment inputs to an in-stream water quality model, the Quality Evaluation and Simulation Tool for River Systems (QUESTOR). QUESTOR integrated the diffuse runoff along the channel network, together with point source discharges from industry and sewage treatment works, and water abstractions for public supply, industry and agriculture.

Scale and temporal aspects

One of the major conclusions of the study was that in hindsight, the modelling in CHESS relied too heavily on models that are very demanding with respect to data. As the SWAT model results focused on longer term means (monthly and annual), the daily time step originally chosen was probably not necessary. The modelling approach is primarily biophysical with economics added on at the side. The summary report (CHESS, 2001) does not reveal how the models were actually linked and what techniques were used in determining appropriate scale levels.

Scenarios and policy measures

Modelling results explore a range of measures to reflect the different stakeholder interests within and beyond the catchment. The results reflect the variability in present day conditions (e.g. climate, soils, agriculture and industry), and the variability in the climate scenarios, both between-catchment and between-scenario.

4.1.5 PEGASE

Introduction

The PEGASE project[2] was conducted to study the impacts of the use of pesticides on the groundwater quality in Europe. First, the presence and transfer of pesticides from the soil surface to groundwater in a number of locations, which are representative for European aquifers, were characterized. Secondly, processes involved in the transport of pesticides from the soil surface to and in groundwater were elucidated. And finally, within the projects tools, such as mathematical models and socio-economic tools, were developed to support the management of pesticide usage towards a sustainable management of groundwater quality. Mathematical models were developed to analyse the transfers of pesticides from the soil surface to the groundwater. The socio-economic tool basically consists of a multi-criteria analysis of a stakeholder analysis with respect to the management of pesticides usage to reach a long-term management of ground water quality.

The PEGASE project was a collaboration of 11 research institutes from 8 European countries. Within the project, a number of test site were selected. Table 4.1 summarizes the test sites with a number of indicators, such as type of formation, surface of test area, water table level and found pesticides.

Table 4.1 Summary of the test sites in the PEGASE project

Site	Type of formation	Area	Water table level	Found or monitored pesticides
Denmark	Clay with fractures		0 to 5 m bgl	Metsulfuron, MCPP
Berkshire, England 1	Unfractured chalk		9 m bgl	Atrazine
Berkshire, England 2	Unfractured chalk		9 m bgl	Atrazine
Trois Fontaines, France 1	Karstified chalk	50 km²	max 30 m bgl	Phenylureas, triazines
Brevilles, France 2	Sand	3 km²	max 30 m bgl	Phenylureas, triazines, acetochlor ...
Krauthausen, Germany	Sand and clay layers	1 ha to 10 km²	1 to 3 m bgl	Isoproturon,
Vredepeel and Rosswinkel, Netherlands	Sand	1.600 m²	1 to 3 m bgl	Bentazone, ethoprophos
East of Martigny in the Canton Valais, Switzerland	Sand and silt	10 km²	1 to 2 m bgl	Atrazine, terbuthylazine, Dinoseb, Isoproturon, Simazine, Diuron.

Interactions water economics

The PEGASE project focuses attention on the quality of groundwater. The socio-economic part of the project basically consists of a multi-criteria analysis of a stakeholder

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[2] **P**esticides in **E**uropean **G**roundwaters: detailed study of representative **A**quifers and **S**imulation of possible **E**volution scenarios, see www.brgm.fr/pegase.

analysis with respect to the management of pesticides usage to reach a long-term management of ground water quality.

Scale and temporal aspects

The PEGASE project has been conducted at the level of river basin management, and the tool is forward looking (simulation) at the long run (i.e. 10 years or so).

Scenarios and policy measures

Within the PEGASE project, future policy measure scenarios with respect to pesticides can be evaluated. These evaluations are based on simulations of pesticide use in the future. So, prerequisite of scenario assessment is that the measures or the scenarios are accompanied by reduction in pesticide use. The scenarios only apply to the local and specific circumstances of the study areas.

4.1.6 AQUATOOL

Introduction

AQUATOOL (Andreu *et al*., 1996) is a generic decision-support system (DSS) for integrated water resources planning and management, including conjunctive use of surface and groundwater. Originally, AQUATOOL was designed for the planning stage of decision-making with respect to water resource management in complex river basins. Subsequently, the system was expanded to incorporate modules relating to the operational stage of decision-making. With computer-assisted design modules, the complex water-resource system can be represented in graphical form that can provide access to geographically referenced databases. Furthermore, AQUATOOL includes basin-management simulation and optimisation modules, an aquifer flow-modelling module, and two modules for risk assessment.

Interaction water economics

More recently, AQUATOOL has been expanded with a new module (Andreu et al. 2005) that contains tools for systematically assessing the resource costs in a water resources system. This module is based on the development of integrated hydro-economic simulation and optimisation models at the river basin scale. These tools can be used for economic analysis of water resource management as required by the WFD. For instance, opportunity cost of environmental measures, such as minimum flows in rivers or minimum volumes in reservoirs, can be calculated and assessed.[3] In particular, two complementary approaches are followed. From optimising economic benefits (optimising approach), the model yields the optimal water allocation in the system. On the other hand, from following a set of operating rules and institutional constraints (priorities and historical rights) the current modus operandi of the system (surface and groundwater

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[3] Andreu et al. (2005) address two types of opportunity costs definitions. The marginal resource opportunity costs (MROC) are defined as the cost for the system of having available one unit less of resource at a specific location and time. The marginal opportunity costs of environmental requirements (MOCER) are defined as the cost for the system of increasing the environmental constraint in one unit.

resources, infrastructure, demands, etc.) are simulated. With the gap between the economic value of the economically optimal water use (optimisation) and the current water allocation system (simulation) any type of management strategy can be assessed with respect to the optimal allocation.

Scale and temporal aspects

In the stage of development and validation, AQUATOOL has been applied to the Segura and Tagus river basins in Spain. The River Basin Agencies in both study areas use a version of AQUATOOL for the efficient management of their water resources. The new module has been applied to the Jucar River Basin in Eastern Spain. Note that AQUATOOL is based on a modular framework, see Figure 1 in Andreu *et al*.(1996). Since AQUATOOLS is based on simulation, it predicts indicators for the future within a dynamic setting.

Scenarios and policy measures

Hydro-economic models provide a tool for a systematic assessment of two complementary measures of the resource opportunity cost and the opportunity cost of the management measures required to achieve the environmental objectives (eg., minimum streamflow) in a water resources system. Theses values, which change dynamically in space and time, can serve as indicators from which we could infer components of the resource and environmental costs required by the WFD. The development of tools integrated within a DSS facilitates its application to different river basins, especially if a validated simulation model is available, as it happens in many Spanish river basins.

4.1.7 Waterwise (Waterwijs)

Introduction

Given the ambitious goals of the WFD, it is clear that in many parts of Europe a substantial reallocation of land will be needed. The Waterwise bio-economic model was developed to provide suggestions with respect to cost-effective and sustainable planning solutions for desiccation and eutrophication of stream eco-systems. Waterwise optimises the land-use in a specific river basin based on the hydrologic situation. This model combines the accuracy of simulation models with the versatility of optimisation techniques to generate land-use patterns along with the appropriate water management, taking into account the preference of stakeholders. In Waterwise the following models have been coupled in the conventional way (the models are run one after each other).

- SIMGRO for the regional hydrology;
- ANIMO for leaching of nitrates and phosphates to groundwater and surface water;
- NATLES for evaluating soil and water site-conditions in terms of the potential type of natural vegetation that can develop;
- DRAM for the development of agriculture (see section 4.3.1).

For handling multiple goals the simple constraint is used: the stakeholder sets constraints on the desiccation of nature areas, the reduction of peak discharges, and the reduction of the nitrate leaching. Waterwise finds the land and water use pattern that satisfies the constraints and at the same time optimizes the revenue from agriculture.

Interaction water economics

The agricultural economics model DRAM is one of the models that is incorporated in Waterwise. It can compute the loss of revenue from agriculture for the new allocation of land, it can also optimize the revenues of agriculture, given constraints on the hydrologic situation.

Scale and temporal aspects

Waterwise has been applied for the Beerze & Reusel stream basin in the Netherlands (45,000 ha). For the bio-economic model, the study region was divided into 4,000 spatial units. A large amount of decision variables, equations and coefficients was used to implement the model in this region. Hence, it is not easy to run Waterwise for large regions.

Scenarios and policy measures

Waterwise is able to compute optimal land allocation (and the corresponding revenue loss) under various conditions; for instance: a maximum nitrogen concentration at the outlet of the basin.

4.2 National economic models

The WFD requires that a distinction is made between the economic sectors, agriculture, industry and household. The preferred model should at least be able to aggregate over sectors (at least the division into three sectors: agriculture, industry and households) and to model interaction between sectors on the relevant output and input markets. The relation between the economic activity and emissions is regarded as an asset. The Dutch models that are taken into account are:

- The Applied General Equilibrium (AGE) of Sustainable National Income (SNI) indicators for the Netherlands (section 4.2.1)
- DEAN; Dynamic Applied General Equilibrium with Pollution and Abatement for the Netherlands (section 4.2.2).
- Bi-regional input-output tables; (section 4.2.3).
- Athena (section 4.2.4)
- MIOW $^{+}$ (section 4.2.5)
- ECM (Environmental Cost Model for Flanders; section 4.2.6)
- Input-output model for water consumption (Spain; section 4.2.7)

4.2.1 AGE model for the calculations of SNI indicators

Introduction

National income is an inadequate indicator of social welfare, because it is either incomplete, misleading, or both. Although there are many directions of improvements, Hueting (*e.g.* Hueting, 1992 and 1995) suggested to correct Dutch national income for environmental losses, i.e. to recalculate National Income, while sustainability standards for environmental themes are imposed. The Institute for Environmental Studies (IVM) has developed an integrated environment-economy model for the Netherlands, i.e. a static Applied General Equilibrium (AGE) model including environmental themes. With this AGE model, Dutch National Income can be corrected for environmental losses, i.e. Sustainable National Income (SNI), see Verbruggen (2000) and Gerlagh *et al.* (2002). The model can be used for comparative static analysis of imposing standards and norms for emissions of environmental themes. So far, the model has been used to calculate SNI indicators for 1990 (Gerlagh *et al*., 2002), 1995 (Hofkes *et al*., 2002), and 2000 (Hofkes *et al*., 2004).

Interaction between sectors

The model identifies domestically produced goods by the sectors where these goods are produced. There are two primary production factors, labour and capital. The model distinguishes three consumers: the private households, the government, and the Rest of the World. In addition to these producers and consumers, there are several auxiliary agents that are necessary to shape specific features of the model. In order to capture non-unitary income elasticities in the model, the consumption of the private households is split into a 'subsistence' and a 'luxury' part. There is an 'investor' who demands investment goods necessary for economic growth, and a 'capital sector' which produces the composite capital good. The model allows for economic sectors to import intermediates from abroad, and economic sectors to produce for both the domestic and the world market.

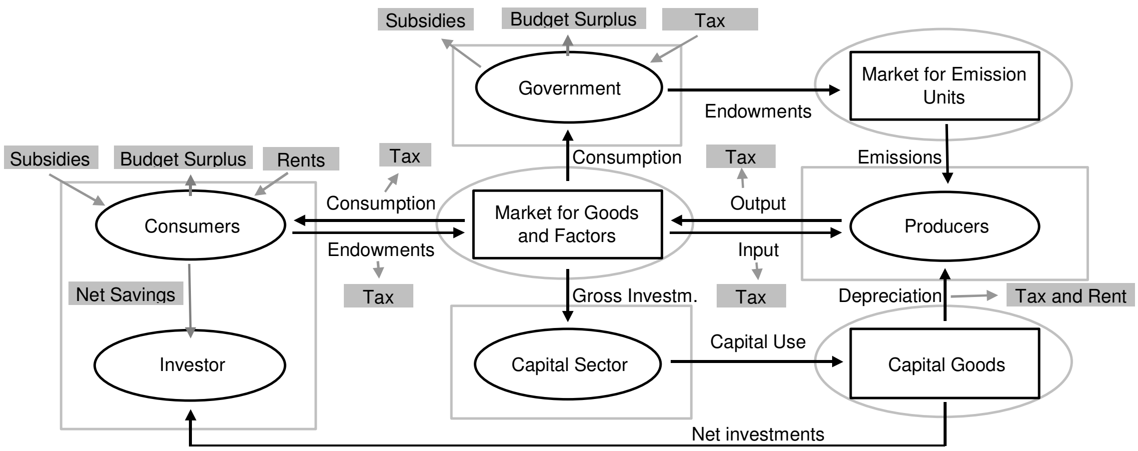

Figure 4.2 Overview of AGE model, Hofkes et al. (2004)

Interaction with water quality and quantity

The model is extended with sectors associated with 9 environmental themes: enhanced greenhouse effect, depletion of the ozone layer, acidification, eutrophication, smog formation (tropospheric ozone), dispersion of fine particles to air, dispersion of toxic substances to water, desiccation, and soil contamination. Except for desiccation and soil contamination[4], aggregated emission units are associated to the environmental themes. In particular, nutrients and phosphates are associated to eutrphication, and some of the prior substances (heavy metals) are associated to dispersion of toxic substances to water. The model has no interaction with water quantity.

Next to the production factors labour and capital, the model distinguishes emission units as production factors as well. As production factor, the emission units are comparable to labour because a reduction of emission units will reduce the output level of production (see e.g. Reinhard, Lovell and Thijssen, 1999). Figure 4.1 shows the market for emission units, supplied by the government in an amount that is consistent with the sustainability standards. Hence, the revenues from the sale of emission units enter the government budget. In addition, there are 'auxiliary' abatement agents that produce goods that are used to reduce pollution in the market of emission units. These goods of the abatement sector are represented by the abatement cost curves for the environmental themes.

Scale and temporal aspects

Initially, the model is static model and was built for the whole Dutch economy. Therefore, it does not distinguish between regions within the Netherlands. In fact, the current version of the model is adapted to the specific economic structure of the Dutch economy as a whole. In theory, the model could be applied to other countries or specific regions in the Netherlands. Practically, however, the adoption of the model to other regions is accompanied by severe requirements of economic and emission data at the level of the region, which are often not available. Moreover, the economic structure of the region requires specific assumptions on several issues, such as the division of economic sectors, income elasticities, and the elasticities of production etc. that deviate from the model at the national scale.

Since the AGE model is static in nature, there are no temporal aspects. The DEAN model deals with temporal aspects (see 4.2.2).

Scenarios and policy measures

For environmental themes, a list of technical measures exists and for all measures the potential emission reduction and the abatement costs are known. The list of measures is then ordered by the cost-effectiveness, i.e. the ratio of emission reduction over abatement costs. Then for each measure, we determine the cumulative reductions of emissions and the cumulative costs. Based on these two series, the abatement cost curves of environmental themes for the reference year are estimated.

The SNI indicator represents a level of National Income at which sustainability standards of the environmental themes are warranted. Economic agents can meet these standards by either investing in abatement technologies or reducing economic activity (i.e. production and consumption activities). The difference between NNI and the SNI indicator represents loss in NNI due to the fact that sustainability standards have to be met for nine environmental themes including two water-related themes eutrophication and dispersion

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4 The environmental themes desiccation and soil contamination handled differently, because these environmental themes have to be resolved completely. There are no emissions associated to economic sectors, there are no abatement sectors and consequently no abatement costs curves.

of toxic substances to water. Additionally, the model indicates the 'sustainable' economic structure of the economy is presented which can change drastically under the sustainability conditions. Also, Value Added and the aggregated emission units of all environmental themes under the sustainability standards are calculated for each sector.

4.2.2 DEAN

Introduction

As the AGE model used for the calculations of SNI indicators, the DEAN model[5] is based on the integrated environment-economic model based on the similar methodology as summarized in Section 4.2.1. The DEAN model is a multi-sectoral *dynamic* applied general equilibrium model for the Netherlands. It focuses attention on the specification of pollution and abatement for several major environmental themes simultaneously (Dellink, 2003).

In addition to the static AGE model summarized in the previous section, DEAN requires additional information and assumptions on capital stocks, depreciation rate, time preference, and growth rates of several economic and environmental indicators (abatement cost curves, for instance).

Interaction between sectors

The economic structure is as presented in Figure 4.2, the abatement technologies are derived from individual technical measures in a similar way (bottom-up), and the sustainability standards are met with a similar trade off between investing in abatement technologies an reducing economic activity.

Interaction with water quality or quantity

Although the DEAN model distinguishes a number of environmental themes, the interaction with water quality or quantity is limited to the emissions of the environmental theme eutrophication. DEAN does not include the environmental theme dispersion of toxic substances to water.

Scale and temporal aspects

With regards to the scale aspects, similar reasoning of the static AGE model applies for DEAN. DEAN is constructed for the Dutch economy as a whole. Since DEAN is a dynamic AGE model, DEAN includes dynamic relationships, such as capital accumulation, and stock pollutants, and subsequently aspects of timing, such as timing of implementing environmental policy, for instance. Moreover, the environmental losses are accumulated over time. In particular, DEAN can provide the adjustment path of the economy towards a more sustainable economy, and it provides accumulated environmental losses over time. In particular, with a dynamic AGE model, the timing of implementing environmental policy can be analyzed. This timing of environmental policy is important for economic agents to make their decisions on consumption, production, and

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5 DEAN is the acronym of *D*ynamic applied general *E*quilibrium model with pollution and *A*batement for The *N*etherlands, see Dellink (2003) for more details.

investing in abatement technologies. Note that the DEAN model can analyze different kind of timing strategies, but it does not provide the optimal timing strategy.

Scenarios and policy measures

DEAN assesses the impacts of environmental constraints on the long-term economic development of the Dutch economy. Similar to the AGE model (section 4.2.1), DEAN includes the trade-off between investments in abatement technologies and reduction of economic activity in terms of slower economic growth. The current DEAN model focuses particularly on air pollution and climate change although it also takes into account eutrophication. DEAN provides economic and environmental results including emission levels and abatement costs for 27 economic production sectors as well as household sector. Different kind of environmental scenarios can be simulated and compared to the benchmark.

4.2.3 Regional input-output tables (RIOT)

Introduction

The WEMPA project has two focal points with respect to the spatial areas considered. In particular, it focuses on the direct and indirect effects of water quality measures derived from the WFD directive at the level of the national economy, and at the regional level, i.e. preferably river basins. At the national level, knowledge on the economy at the national level suffices for analysis as regional interdependencies are ignores. If the focus of the project switches to the regional level, the requirement for more detailed knowledge on regional economies grows. For the Netherlands, Statistics Netherlands usually generates Input-Output tables for the whole Dutch economy,[6] but not for regional economies.

The collaboration of University of Groningen and Statistics Netherlands has resulted in the construction of regional Input-Output (RIOT) tables for 14 regional economies in the Netherlands, see Eding *et al*. (1995), RUG/CBS (1999) and Eding *et al*. (1999). The RIOT tables are primarily used to construct statistics.

Interaction between sectors

The RIOT tables are derived from the National Account and they comprise supply (supply of commodities by original industry) and use (use of commodities by other industries and final demand) tables. Although the RIOT tables are based on the year 1997, the regional structure of the economy originates from 1992. Basically, the construction of the RIOT tables consist of a numbers of steps, namely the classification of commodities and industries, and the estimation of regional industrial supply and use of commodities, regional final demand, foreign trade, and interregional trade.

In the Dutch National Account, 850 commodities and 250 industries are distinguished. If these numbers of commodities and industries would have been desaggregated over 14 regions, the total number of required cells would have exceeded one million cells. So, the

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[6] Interestingly, the I-O tables for the whole Dutch economy are used as inputs in the AGE model used for the calculation of SNI indicators, and the DEAN model.

Dutch RIOT tables are compressed to 206 commodities and 139 industries,[7] see Eding et al. (1999). Per region, the number of commodities or industries may vary. The supply and use of commodities are derived from the regional production data. Although more sophisticated methods are available, final consumer demand and government expenditures are derived from the National Accounts. Those sophisticated methods are accompanied by more severe data requirements, which are hard to meet. Finally, although foreign trade and interregional trade can be distinguished, the estimation of both kinds of trade are integrated into one estimation procedure.

Interaction with water quality or quantity

The RIOT tables are primarily used to construct statistics. Consequently, the RIOT tables cannot be used for additional economic-environmental relationships to integrated hydro-economic models. However, these RIOT tables are very useful as input of these kind of models, especially if the hydro-economic model considers regional relationships as well. Moreover, both AGE models, SNI in Section 4.2.1 and DEAN in Section 4.2.2, use similar Input-Output tables at the national level. Note that the RIOT tables are expressed in monetary terms (both supply and use tables). Since we are interested in a combination of monetary and physical indicators, it is worthwhile mentioning that there have been attempts to construct physical IO tables as well, c.f. Konijn (1994) and Hoekstra (2003). In particular, Hoekstra (2003) calculated Physical IO tables (PIOT) for to iron, steel and plastics in 1990 and 1997. Moreover, in his analysis he distinguished water supply industry as a sector, and he considered emissions to the natural environment in his model as well.

Scale and temporal aspects

The RIOT tables are available for 14 regions, twelve provinces and the two large metropolitan areas of Amsterdam and Rotterdam. As a consequence, the RIOT tables for the provinces North-Holland and South Holland are excluding the Amsterdam and Rotterdam metropolitan area respectively. The available RIOT tables present annual statistics and are constructed for one particular year. The underlying economic structure of the Dutch RIOT tables originates from the year 1992.

Scenarios and policy measures

Since the RIOT tables just present statistics, the calculation of policy measures is infeasible.

4.2.4 Athena

Introduction

Athena is CPB's model for analysis of sectoral aspects of the Dutch economy. It is used for short-term forecasts, medium- and long-term scenario-building and for policy analysis. (Vromans, 1998)

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7 From the University of Groningen website, aggregated Dutch RIOT tables for 14 regions can be downloaded. These tables are aggregated as the number of commodities and industries has been limited. More detailed tables are available upon request.

Interaction between sectors

For each of distinguished branch of industry, Athena produces a confrontation of resources and expenditures. With the exception of private consumption, the model is characterised by a bottom-up approach in which the macro total of a variable follows the sum of sectoral figures. The labour market and on a branch level the product market mutually affect each other. Foreign influences are exogenous. How policy measures affect the sectoral structure depends in the first place on the price elasticities.

Interaction with water quality or quantity

Water (or emission to the environment) is not incorporated in Athena.

Scale and temporal aspects

The model's ability to show changes in the production pattern makes it particularly appropriate for exploring long-term scenarios and for policy variants with different impacts upon individual branches. The model has been used for specific analysis of the consequences of polices with long-term horizons that have different impacts upon individual sectors.

Scenarios and policy measures

Athena has been used to assess the economic effects of environmental policy for the election programme of GreenLeft (1998).

4.2.5 MIOW$^+$

Introduction

In 1986, MIOW[8] – a decision support tool for individual companies – was developed to organize and visualize certain current and future market aspects, such as market situation, international environment and resilience. In the late 1990s, IVM turned MIOW into MIOW$^+$, which differs from MIOW in the sense that it organizes and visualizes quantifies market aspects (market situation and resilience) in the case of investments in environmental measures including water quality related measures. MIOW$^+$ is based on a questionnaire on current and expected developments in financial issues, competitiveness, production process, position in the product chain, and investments in environmental measures.

The MIOW$^+$-method is an interactive computer program to analyse the financial effects of future environmental measures for individual companies, see Van der Woerd et al. (1998) [9]. The tool derives indicators on aspects such as market situation, resilience and environmental measures. Environmental measures can be assembled in a business-environmental plan (BMP), which companies make up as part of sectoral covenants. However, this is not essential, as every cost price raising environmental measure can be used within MIOW$^+$ for financial analysis. MIOW$^+$ tool has been developed for medium-

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8 MIOW is the Dutch acronym of *Marktsituatie, Internationale Omgeving en Weerstandsvermogen*, i.e. Market situation, International environment, and Resilience.

9 The manual of Van der Woerd et al. (1998) uses 1995 as the base year.

sized and large industrial companies, i.e. companies with 50 employees or more. Van der Woerd et al., (1998) argued that other applications of MIOW$^+$ is accompanied by specific requirements.

Interaction between sectors

The MIOW$^+$ method is usually applied on individual firms or at the level of economic sectors. There is no interaction between sectors.

Interaction with water quality or quantity

Within the MIOW$^+$-method, companies can compare costs of additional environmental measures to the current and expected financial situation without additional environmental measures. So, MIOW$^+$ indicates how environmental costs might affect the continuity of business. The financial situation is characterised by means of a number of internal and external indicators. The weighted average of the internal indicators results in a score for Resilience and the average of the external indicators results in a score for Market Situation. The essence of the method is that the values of Resilience and Market Situation determine the possibility to absorb extra environmental costs internally, or to transfer them to clients.

MIOW$^+$ is a means to get as objective a view as possible of the financial position of an individual company, looking ahead to the next four years. Completing the questionnaire as well as interpreting the results demands financial expertise. An expert opinion is necessary, particularly with regard to future developments. The same goes for the assessment of the competitive position. It is recommended that the results of MIOW$^+$ be used as a starting point for negotiations between the company and the government.

Whether or not a company is doing well is not assessed the same way across sectors. The valuation of the internal indicators in particular depends upon the production process, the build-up of cost price and the place in the product column. For instance, there are significant differences between industry, trade and services.

Scale and temporal aspects

As mentioned above, MIOW$^+$ can be applied to individual companies or economic sectors. There is no geographical distinction. With respect to the time aspect, MIOW$^+$ is backward and forward-looking. On the one hand, MIOW$^+$ summarizes the relevant economic circumstances in the (recent) past and on the other hand it requests for (potential) measures and expected economic circumstances.

Scenarios and policy measures

The MIOW$^+$ method is used to make an inventory of the (potential) technical measures to reduce emissions. In addition, the expected economic consequences and circumstances of particular (technical) measures are summarized.

4.2.6 Environmental Costing Model ECM for Flanders

Introduction

The Flemish BAT-Centre of Vito (the Flemish Institute for Technological Research) has developed the Environmental Costing Model (ECM) for Flanders. This model aims to determine the costs of environmental policy and to contribute to a more efficient environmental policy by indicating how environmental targets can be realised in a cost effective way. Initially, this tool has been developed as a decision support tool for the Flemish government.

ECM is divided into four modules, data module, calculation module, reporting module, and relational module. The data module summarizes the current and future state of the environment, background variables, such as depreciation rates and time preferences, and a coherent database on environmental measures with their reduction potential, costs, efficiency and penetration rate. Preferably, the environmental measures are gathered at the lowest possible source of emissions. The reporting module is just a user-friendly interface in which users can run simulations by setting key variables and imposing conditions. Finally, the relation module links all other modules.

Interaction between sectors

The relation module can be used to look for opportunities to link ECM to other models such as ecological models and economic models. The current version of ECM has no interactions between economic sectors.

Interactions with water quality or quantity

So far, the ECM has been applied to three pollutants, which are not water-related emissions or priority substances.

Scale an temporal aspects

The model is used at a national scale, and it distinguishes sources of emissions. Since ECM has been developed as a decision support tool, it is forward looking model based on the present situation and future developments.

Scenarios and policy measures

Given a reduction standard, the calculation module of ECM determines the optimal allocation of emission reduction efforts between different target groups. The optimisation is based on the cost effectiveness of sets of measures, where it takes into account multiple pollutant effects. Within this module, abatement cost curves are determined. Moreover, it evaluates the cost-effectiveness of different kind of economic instruments, such as emission charges or tradable emission permits.

4.2.7 Input-output model for water consumption

Introduction

This model is used to determine which economic sectors consume the greatest quantities of water, both directly ad indirectly and to what extent water may become a limiting factor in the growth of certain production sectors (Velazquez, 2005).

Interaction between sectors

This input-output model of sectoral water consumption is based on the extended Leontief input-output model that was extended to model energy use. The analysis is applied to Andalusia, a region that is characterised by water shortage.

Interaction with water quality or quantity

Water is distinguished as one of the 25 sectors in the model. Each sector's direct water consumption is known. The model allows the ex-ante evaluation of economic and environmental policies oriented towards water saving.

Scale and temporal aspects

The Input-Output model for water consumption was developed for Andalusia only and contains data of one year.

Scenarios and policy measures

Valazquez (2006) does not present scenarios or different policy measures.

4.3 Sector models

In policy analysis aimed at optimizing water management, water distribution models are used that simulate the distribution of water over the water network and allocating water to sectors as agriculture and inland navigation. These models describe the relationship between water quantity and the economy (see Figure 2.1). As stated in chapter 2, those models are not considered, unless they are used as underlying model for water quality predictions.

This section discusses models that determine the economic activity of sectors related to emissions generated and whenever possible to the quantity of water available. Ideally, the results of sector models have to correspond to the results of the national economic model. The list of sector models comprises the following models:

- DRAM; the Dutch Regionalised Agriculture Model (section 4.3.1);
- Agricom; an agricultural model developed at RIZA (section 4.3.2);
- Inland navigation model. (Scheepvaart model, section 4.3.3);
- Atlantis, a model for public water supply (section 4.3.4).
- Waterpas, modeling the relation between the surface water level and farm economic results (section 4.3.5)
- SEO water recreation model (section 4.3.6).

4.3.1 DRAM

Introduction

The focus of DRAM is on regional and national agricultural production and interactions between agricultural activities through agricultural input and output markets. Figure 4.3 gives a schematic presentation of DRAM. DRAM includes 25 marketable or final outputs, intra-sectoral produced inputs, and variable inputs. Agricultural outputs are produced by agricultural activities. DRAM describes 32 agricultural activities with technical (input-output) and economic variables and parameters differentiated per region, not per farm. In principle, every region is treated as one farm.

Interaction with economy

The core of the mathematical programming model, described in the middle of Figure 4.3, is the profit maximizations from agricultural activities at the national level subject to economic, technical and policy constraints. DRAM assumes that there exists an optimal level of agricultural input use and output production. This optimum allocation of inputs and output production is reached when marginal costs are greater than or equal to marginal revenues for all agricultural activities in the model. This condition for an optimal solution is derived from the standard economic assumption that farmers behave as profit maximizing agents.

Technical input coefficients, such as the total use of nutrients (nitrogen (N) and phosphorus (P)) either from animal manure or mineral fertilizer, young animals and roughage (grass and maize) per activity, are exogenous. Every activity in the model produces a certain type of output. A realistic representation of technology requires that the same type of output can be produced with different input-output coefficients. This is taken into account by including different input-output coefficients per activity per region. Remaining variable costs (concentrates, pesticides and other variable inputs) per activity are modelled using a quadratic variable cost function. The approach of Positive Mathematical Programming (PMP) is used to calculate the parameters of the cost functions in such a way that the observed activity level is almost exactly reproduced (Howitt, 1995).

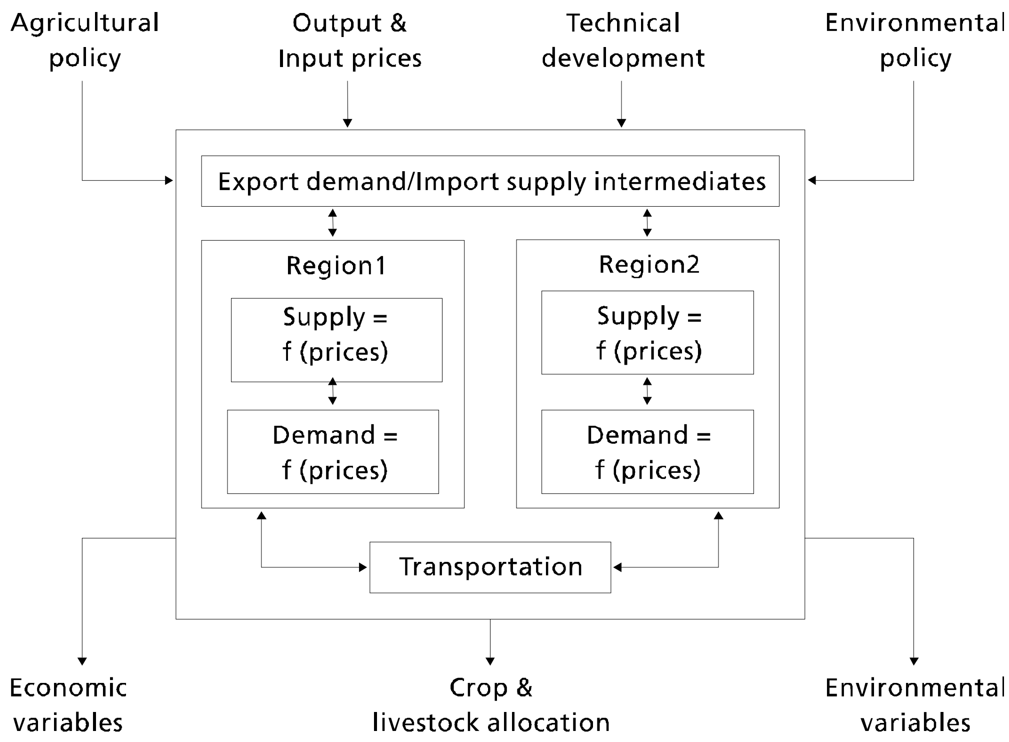

Figure 4.3 Schematic representation of DRAM.

Prices of most outputs and inputs are treated as exogenous variables, as they are assumed to be determined at the internal EU market or world market. For these inputs and outputs, the small country assumption is applied. Regional prices are used to take into account possible regional differences in output and input quality, farm size and transport cost. Fixed inputs in the model are land and quota. Agricultural land and quota for sugar beets are assumed fixed at the regional level. Quota for milk and starch potatoes are assumed fixed at the national level. Fixed inputs in DRAM are valued by the shadow prices on the regional or national balances. The shadow price of a fixed input shows the increase in the objective function resulting from a marginal increase in the fixed input. Capital and labour are assumed not to be restrictive at the sectoral level.

Interaction with water quality

DRAM computes the nutrient surplus. This surplus can easily be computed to the emission to the water system. Fertilisation requirements of the crops in combination with the exogenous yield levels can be fulfilled using nutrients from animal manure and mineral fertilizer. Hence, application of animal manure and mineral fertilizer per crop are endogenously determined within the model.

Interaction with water quantity

DRAM does not contain a relation with water quantity presently.

Scale and temporal aspects

DRAM distinguishes between 66 regions (figure 4.4). The selection of regions in DRAM is based on two arguments, homogeneity of soil and environmental impacts. Different soil types have different yields and the regions distinguished by DRAM are characterized by different predominant soil types. Besides differences in yields per soil type, environmental impacts can also be soil type specific e.g. intensity of nitrate leaching. Out of the distinguished fourteen regions, seven regions have clayey soil, five regions have sandy soil and two regions have peaty soil.

Figure 4.4 Agricultural regions in the Netherlands as incorporated in DRAM.

Scenarios and policy measures

The CAP includes price subsidies, direct income payment per hectare and animal, in some cases these payments differ per region, production quotas, set-aside regulations, premiums for extensive production systems and investment support. The Dutch manure and nutrients policy includes standards for the nutrient contents of concentrates, agricultural outputs and animal manure, threshold levels for nutrient surpluses per crop per region and application standards for nutrients from animal manure. According to the principles of explicit policy modelling and because of the relevance for Dutch agriculture, it is necessary to model all these measures and standards as explicitly as possible.

4.3.2 AGRICOM (AGRIcultural Cost Model)

Introduction

AGRICOM was built to calculate costs and benefits for agriculture of the second report on water management. AGRICOM calculates the costs and benefits of agriculture during wet and drought conditions.

Interaction with water quantity

The water quantity relations are modeled in MOZART (Model for the unsaturated zone for national analyses and regional applications)

Interaction with water quality

Scale and temporal aspects

The model computations are done for points of a 500*500m grid, the results are reported per district (130 districts exist in the Netherlands). The computations are done in 10 day intervals (shorter intervals are also possible). The results are presented per year.

4.3.3 Bio-physical models

Introduction

As an example of a bio-physical model the article of Lacroix et al. (2005) is used. Lacroix et al., 2005 describe the physical relations that are relevant to determine the effect of measures on water quality (or on emission). For instance the growth of plants is simulated the take up of nutrients and the emissions to the environment. The objective of this paper is to study the probabilistic cost-effectiveness of the farm management practices supported by the EU for reducing nitrate pollution. Their method consists in using a bio-physical model to evaluate the environmental and economic impact of various scenarios characterized by a set of farm practices.

Interaction with economics

The costs of the measures are calculated at the catchment level on the basis of crop model outputs. The scenarios with lowest costs for farmers are identified.

Interaction with water quantity

The climate is taken into account, thus the inter-annual variability of the availability of water is used in the crop model.

Interaction with water quality

The nitrate concentration in drained water at the catchment level is predicted in relation to climate characteristics and farm practices by means of crop models (based on the nitrate leaching and the depth of drained water).

Scale and temporal aspects

The scenarios are evaluated for a catchment area covering 36 fields and for 6 (different climatic) years.

Scenarios and policy measures

Six scenarios are considered. Four of them simulate farm management practices that have been suggested by the EU with a view to reducing agricultural nonpoint pollution. The scenarios consists of: code of good agricultural practice, reduction of the nitrogen fertilization level by 20% relative to the optimum level and establish catch crops before all spring crops.; remove a plot of land from production and convert it to grassland.

4.3.4 WaterPas (Farm model)

Introduction

WaterPas describes the integrated relation between water management, agriculture and environment on a dairy farm. With the WaterPas model the risk of wet and drought harm on both field and farm scale can be calculated. Models are coupled for water flow, crop growth and grassland management. With the use of the Framework Integrated Water Management a maximum integration between the different modules is accomplished (de Vos et al, 2004).

Interaction with economics

The grassland management model simulates the use of the distinguished parcels in the farm production process. Based on the grass production results, the revenue of the farmer is computed.

Interaction with water quantity

WaterPas is able to simulate the water balances based on daily weather data, groundwater regimes, soil and farm characteristics. It computes the corresponding grass production.

Interaction with water quality

WaterPas is also able to simulate the nutrient balances, bases on groundwater regimes, soil and farm characteristics.

Scale and temporal aspects

Based on daily weather data, groundwater regimes, soil and farm characteristics, WaterPas is able to simulate grassland management of a farm during a year.

Scenarios and policy measures

Results of the program gives insight in the effects of, as an example, drought abatement and water level control on the agricultural and economic yields.

4.3.5 Inland Shipping model (Scheepvaartmodel)

Introduction

The inland shipping model answers the question what additional costs the shipping sector encounters when the river water levels are decreasing. Only the water table levels and water flows can be adjusted. Water table levels need to be computed separately on the basis of water flow data from e.g. the RIZA "Distributiemodel" (Water distribution model). The stream of goods is fixed in an underlying layer. Basic data (fleet, basic financial data) are from 1997. The output of the model is a table of costs per shipping class. Note that these costs are average costs for the Netherlands as a whole. Unfortunately, it is not feasible to calculate the distribution of costs across regions (river basins, in particular) with this model.

Interaction with economy

The inland shipping model answers the question what additional costs the shipping sector encounters when the river water levels are decreasing.

Interaction with water quantity

Interaction with water quantity is obvious. With a lower water table, ships cannot be fully loaded and hence, the cost per unit of goods shipped will increase. Compared to other sectors (agriculture, energy) the impact of low water supply for inland shipping is not very large (approx 3% less turnover). The model assumes fixed distribution of transport volumes over the modalities. In practice, transport entrepreneurs will shift from shipping to other means of transport when shipping prices increase due to low water tables.

Interaction with water quality

The model has no interaction with water quality.

Scale and temporal aspects

The model incorporates all major inland shipping routes in the Netherlands. For each route, relations between water levels and maximum transport loads are fixed. The output (additional costs) is at national level, i.e. one figure for the Netherlands as a whole for an entire year. The water flow input data are per decade. Output can be regionalized manually, it is also possible to calculate costs for a specific period, this also requires a manual adjustment.

Scenarios and policy measures

The model has been extensively used in the National Drought Study, where the impact of drought for the economy has been calculated, and where mitigation strategies are being developed (RIZA 2005). However, the model is static, i.e. the parameters related to the capacity of the national fleet and the transport volumes are fixed (1997 data). Expected changes in the structure of the inland shipping sector are not incorporated, although it is expected that these changes will have more impact on shipping costs than fluctuation in discharge levels. Hence, the results of the model on the longer term are probably not very reliable.

4.3.6 ATLANTIS

Introduction

This model calculates the costs of public water supply depending on the demand, the preferences with respect to available water resources (groundwater, surface water), and the quality of these resources. Atlantis is a renewed model of the precursor model DRISIM. Atlantis is a decision-support model for the development, evaluation and comparison of solutions for (future) infrastructure to enable supply of drinking and industrial water based on environmental pressure and costs. Atlantis determines the most effective spatial distribution of a drinking water grid, given certain future demand for water. The following aspects of the infrastructure have been taken into consideration: the amounts of extracted surface water and groundwater, the costs of the drinking-water production and the effects of this production on the environment (RIZA 2002).

Interaction with economy

The costs of the drinking-water production are taken into account.

Interaction with water quantity

Water quantity is a variable both at the demand and at the supply side. The spatial distribution of future demand can be entered as an exogenous factor in the model, on the basis of which the model will compute the most effective corresponding grid. Other way around, a certain grid with given drinking water production capacity can be entered, on the basis of which the model computes the consumption distribution, the associated costs and certain environmental aspects (use of raw materials, energy consumption, and production of remnant substances). The impact on the decrease of groundwater and costs for mitigating measures is also computed.

Interaction with water quality

The model assumes a standard water quality (and hence fixed associated costs) for groundwater and surface water used for drinking water. Hence, water quality is variable in the model. The model may possibly be further developed by making costs for water delivery variable at various levels of water quality.

Scale and temporal aspects

Atlantis is a model at national level. It links spatial discrepancies in demand and supply by a grid of pipes. As input data for Atlantis, use can be made of topographical map of the Netherlands; map of dried areas in the Netherlands; maps with the development of groundwater quality; water consumption data; data on extraction points and the water supply grid; data on location and volumes of groundwater extraction (also input for NAGROM). As far as demand is concerned, the most commonly used method is to enter demand data aggregated at the level of the drinking water companies. Supply is entered at the level of specific water intake points. The output is a spatial pattern of the optimum infrastructure for water supply at a given future water demand and other conditions. Data entry and output is on an annual basis.

Scenarios and policy measures

Atlantis is useful for assessing the impact of scenarios and policy measures. The model has, among others, has been applied to the National Environmental Outlook 1997-2020. The consequences of the three future scenarios of the Bureau for Economic Policy Analysis (CPB) for the drinking-water infrastructure have been determined. The following conclusions can be drawn from the calculations performed (Gaalen and Mulschlegel, 1999):

a. Extractions of all types of water will increase in the period 1995-2020 in all three future scenarios. The proportion of groundwater to surface water used for the production of drinking-water will shift from 1:2 in 1995 to approximately 1.5:1 in 2020.
b. As a result of policy and infrastructural limitations the total amount of extracted groundwater for the production of drinking-water in the period 1995-2020 remains under the total amount of groundwater permitted for extraction according to the extraction permits of 1988.

Interaction with other models

Atlantis does not require the output of other models. However, the model is useful in interaction with other models. Making use of each others output, integral studies can be carried out. Interaction is possible with MOZART, NAGROM, DEMNAT. The output of Atlantis is directly applicable for policy decision support. The computed volumes of surface water extractions for drinking water purposes can be used in MOZART and NAGROM.

Validation

Atlantis is a consensus model of VEWIN, RIZA en RIVM. In 1995, the validity has been tested by those three organizations and been considered satisfactory. Reliability of the model can be illustrated by the use of certain scenarios. The most determining factors affecting the model's results are:
a. The entered spatial distribution of supply and demand points and its' connecting grid;
b. The future development of drinking water demand.

4.3.7 SEO Water Recreation model (WR-model)

Introduction

In 1994/1995, SEO developed the Water Recreation model which describes and projects the phenomenon of water recreation in the Netherlands in the recent past and the near future. The model has been revised in 2001 on three parts: 1) the model has been updated, 2) the model has been extended for the user, and 3) the model has been adapted to present requirements. The model calculates the annual output of demand for water recreation and the related expenditures and employment (Berkhout et al., 1996). The model parameters are based on surveys conducted in the year 1995. The model consists of a combination of two models determining respectively:

1. WR1: the intensity of water recreation activities and related expenses and employment;

2. WR2: the water quality index.

Model WR-1 predicts the demand for water recreation in the Netherlands. This demand is subdivided in: (a) sunbathing/swimming; (b) sailing/surfing; (c) fishing; and (d) boating.

The demand depends on personal characteristics, weather conditions, and the quality of waters as perceived by the recreants (represented as a Water Quality Index). The demand is calculated from three indicators, namely the numbers of visits counted for (i) day trips; (ii) holidays of Dutch people; and (iii) holidays of foreigners. It is assumed that the demand is fully met. Obstacles that might reduce the number of visits, like traffic jams on routes to the recreation sites, and e.g. lack of accommodation, are ignored.

Based on average expenditures per visit, the WR1-model determines the total expenditures and, using data on average labour productivity, the effects on employment.

For each activity the water quality aspects are determined that contribute to the perception of the water quality. These aspects are expressed as a number between 0 and 10 for each community. In the WR2-model these numbers are aggregated to an average Water Quality Index (WQI) for each of the tourist areas that are distinguished in the Netherlands using the intensity of the activities in each area as a weighting factor.

Scale and temporal aspects

The model calculates results on a seasonal or yearly base. The planning horizon for the predictions of the WR1-model is 2020. Predictions can be made using one of three scenarios for future development that were developed by the Dutch Central Planning Bureau: Divided Europe, European Coordination and Global Competition. The results of the model are aggregated to the level of 14 (tourist) areas in the Netherlands. Four of these areas are coastal or estuarine.

Scenarios and policy measures

The WR-model is able to determine how all kinds of scenarios and policy measures aimed at improving the water quality affect water recreation. As input for the model the perception of the water quality is needed. The model is applied for several scenarios (of CPB). Besides scenarios the model offers other variables to show the effect on output. Examples of variables are: good verses bad season, changes in quality, and intake of foreign tourists.

5. Model selection

For the model selection, the relevant relations that have to be modelled are presented in Chapter 2. The extensive screening procedure is explained in Chapter 3. The long list of possibly useful models is presented in Chapter 4. In this chapter these models are evaluated and screened to determine how useful they are for the water economic model for the Netherlands. We focus first on the essential relations that form the spine of the water-hydrology model. Data availability and model specifications are included in the screening procedure in the second stage.

5.1 Hydro-economic models

Seven models discussed in section 4.1 may provide suitable relations to combine the economic and hydrological aspects of the water-economics model to be built. The Maipo-river model, RIWU-model of the Danube, the Herault model, CHESS, PEGASE, AQUATOOL and Waterwise. None of these models is capable of simulating the Netherlands' situation. Although Waterwise is applied to the Netherlands, it simulates a specific regional river basin in the Southern part of the Netherlands. The other models are used for foreign river basins. The Maipo-river model is the only one that has been applied in other river basins too; it has also been applied to the Mekong delta (Ringer and Cai, 2003). In order to be useful, these foreign models have to be adapted to the Dutch circumstances.

Table 5.1 Screening of hydro economic models on level 1

	Hydro economic models						
Criteria	Maipo	RIWU	Heraul	CHES	Pegas	Aquatoo	Water
Does the model allow policy measure analysis	Yes	Yes		?	Yes	Yes	Yes
National water quality policy issues + results	No	No	No	No	No	No	No
Regional water quality policy issues	Only Quantit	Only Quantity	Yes	Partly	Yes	Yes	Yes
Fits modelling chain	Yes	Yes		?	Yes	Yes	No
Assessment of financial or economic effects	?	?		No	Yes	Yes	Yes
Model address medium to long-term time scale	?	?		Yes/No	Yes	Yes	No
Passes to second level	No	No	No	No	No	No	No

Table 5.1 shows the results of the first level screening of the hydro-economic models. None of the hydro-economic models taken into account will pass to the second level, due to the fact that they are not able to model water quality issues at national level and to produce relevant results at the national level. Therefore, we have to assess the national economic models seriously to determine whether they are suitable to be integrated in the

Water Economics Model. The foreign hydro-economic models are likely to provide information about the modelling framework that could be used to develop the WEMPA.

5.2 National economic models

The Dutch national economic models (the AGE models to calculate SNI, DEAN and Athena) do not model water quality issues nor water quantity issues explicitly. SNI and DEAN are able to model the emission of pollutants into the environment. The three Dutch national economic models can be utilised to model the interaction between sectors. MIOW^{+} and ECM score well in Table 5.2, but they do not model (economic) relations. In fact, they are decision support systems; for instance MIOW^{+} does not incorporate the interaction between sectors.

Table 5.2 Screening of national economic models on level 1

	National economic models						
Criteria	'SNI'	DEAN	I-O-model	Athena	MIOW^{+}	ECM	Spain
Does the model allow policy measure analysis	Yes	Yes	No	No	Yes	Yes	Yes
National water quality policy issues + results	No[1]	No[1]	No	No	Yes	Yes+ No	No
Regional water quality policy issues	No	No	No	No	No	Yes	Yes
Fits modelling chain	Yes	Yes	na[2]	Yes	No	No	No
Assessment of financial or economic effects	Yes	Yes	No	No	Yes	Yes+ No	Yes
Model address medium to long-term time scale	No	Yes	No	?	Yes	Yes	No
Passes to second level screening	Yes	Yes	No	No	No	No	No

[1] Not water quality explicitly but levels of emissions.
[2] Only input data

The input-output models do not model the relations but may provide useful input data. The general equilibrium models might be useful to implement in WEMPA framework (see Chapter 2). Although they do not fully fit the screening criteria, they nevertheless pass on to the second level. The potential role of the general equilibrium models in WEMPA is to model the interaction between sectors and to model emissions at sector level.

Table 5.3 Screening of national economic models on level 2

	National economic models						
Criteria	'SNI'	DEAN	I-O-model	Athena	MIOW	ECM	Spain
Specification of supply and demand functions	Yes[1]	Yes[1]	Yes	Yes	No	No	Yes
Are prices endogenous	Yes	Yes	No	Yes	No	No	No
Is the interaction with the world modelled	Yes	Yes	Yes	Yes	No	No	Yes
Useful for priority issues	Yes	No	No	No	Yes	Yes	No
Relevant water use functions or emissions included	Yes	Yes	No	No	Yes	Yes	No
Priority substances included	Yes	Yes	No	No	Yes	Yes	No
Input data available	Yes	Yes	Yes	Yes			No
Can the costs and/or effectiveness of measures be estimated	Yes	Yes	No	No			No
Passes to third level screening	Yes	Yes	No	No	No	No	No

[1] No water quantity.

Table 5.3 shows that SNI and DEAN are also useful at the second level of screening. Although DEAN is capable to simulate the future at the medium or long term, it does not include priority substances such as heavy metals. For SNI it is the other way around. Heavy metals are included, but the model simulations are short-term results.

Table 5.4 Screening of national economic models on level 3

Criteria	'SNI'	DEAN
Evaluation on national scale	Yes	Yes
Evaluation on regional scale (7 river basins)	No	No
Are results accurate	Yes	Yes
Passes all levels screening	Yes	Yes

Both 'SNI' and DEAN are not able to evaluate measure on the river basin level. Therefore, they do not pass this screening level. However, they are the most suitable national economic models to be incorporated in WEMPA.

5.3 Sector models

The sector models DRAM, ATLANTIS and Water Recreation-model all pass the first screening level (see Table 5.5). The Shipping model is not able to assess national and regional water quality issues.

Table 5.5 Screening of sector models on level 1

	Sector models						
Criteria	DRAM	Agricom	Lacroix	WaterPas	Shipping model	Atlantis	Water recreation
Does the model allow policy measure analysis	Yes	Yes	Yes	Yes	Yes	Yes	Yes
National water quality policy issues	Yes	?	Yes	No	No	Yes	Yes
Regional water quality policy issues	Yes	?	Yes	No	No	Yes	No
Fits modelling chain	Yes	Yes	?	?	?	No	Yes
Assessment of financial or economic effects	Yes	?	Yes	Yes	No	Yes/No	No
Model address medium to long-term time scale	No	No	No	No	?	Yes	Yes
Passes to second level screening	Yes	No	No	No	No	Yes	Yes

DRAM and ATLANTIS both contain supply and demand functions and are able to compute prices of relevant goods and services endogenously. The water recreation model does not contain these economic relations. DRAM and ATLANTIS pass to the third level. Although the Water Recreation model does not pass the second screening level, it is the only useful model that can easily determine the effect of water quality on water recreation in the Netherlands. For this reason, it is also screened at the third level. The Lacroix en WaterPas models allow policy measure analyses of some measures that are relevant for WFD. However they only compute the effect on the farmer's income, the costs are computed as the difference with the income under autonomous development. The long-term time scale is not incorporated in these models. These bio-economic models might be useful to compute input data for the sector models.

Table 5.6 Screening of sector models on level 2

Criteria	DRAM	Agricom	Atlantis	Water recreation
Specification of supply and demand functions	Yes (no water)	Irrigation	Yes (no water)	No
Are prices endogenous	Yes	Irrigation	Yes	No
Is the interaction with the world modelled	Yes (prices)	No	Yes (prices)	
Useful for priority issues	Yes	No	Yes	Yes
Relevant water use functions or emissions included	Yes	Yes	Yes	Yes
Priority substances included	Yes	No	Yes	Yes
Input data available	Yes	Yes	Yes	Yes
Passes to third level screening	Yes	No	Yes	No

Table 5.7 Screening of sector models on level 3

Criteria	DRAM	Atlantis	Waterrecreation
Evaluation of costs at national scale	Yes	Yes	Yes
Evaluation on regional scale (7 river basins)	Yes	Yes	No
Are results accurate	Yes	Yes	Yes
Passes all levels screening	Yes	Yes	Yes

DRAM and ATLANTIS are the most suitable models to represent agriculture and drinking water in WEMPA and we, therefore, suggest to consider the incorporation of both in WEMPA.

6. Conclusions and recommendations

6.1 Conclusions

The aim of the project is to develop an integrated and operational water and economy model. This model enables the analysis of the integral effects of measures implementing the EU Water Framework Directive (WFD) in the Netherlands. An important requisite of this model framework is that it must be shaped in such a way that it will be suitable for applying cost effectiveness analysis of measures. In this document the availability and usefulness of (water) economic models to become a part of the model framework to be developed is analysed.

A model that satisfies all relevant criteria is not readily available. The existing foreign hydro-economic models are not able to assess the effects of measures at a national scale. Hence, a water and economy model has to be constructed and it will be based upon existing national economic and sector models. From the national economic models assessed, DEAN is the most appropriate model to incorporate in the model framework. DEAN also distinguishes the sectors explicitly prescribed in the WFD: agriculture, households and industry. Moreover, only nutrients are included in the DEAN model, and regional impacts cannot be addressed directly. Sector models have been analysed to determine whether these models are suitable to integrate in the model framework. DRAM and Atlantis are suitable models. The Water Recreation model is the only relevant model for this sector and is for this reason interesting for WEMPA.

At a lower aggregation level, bio-economic models provide more detailed insight in the effect of possible measures. However the economic component of these models is rather weak, they do not go beyond the farm level. These bio-economic models might be suitable to deliver information to the sector models on the way measures affect the farm level.

6.2 Recommendations

Given the fact that a suitable model is not readily available, a model framework has to be developed that incorporates the links between water and economics as provided by the foreign hydro-economic models. Interactions between economic sectors can be best modelled by DEAN, or by a new model that contains the strong elements of DEAN. DRAM and ATLANTIS could be used to model the implications of the WFD for agriculture and households. For the industry, an appropriate sector model is not available. For this last sector DEAN could be used.

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WEMPA reports

Reportnumber	*Authors*	*Title*
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WEMPA Report-02	Paul Baan Aline te Linde	Inventory of water system models
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